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Recommendations for Cost-Benefit Analyses in Projects with Carbon Benefits from Trees

Pablo Ordóñez[*]

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Abstract

This technical note provides practical recommendations for conducting rigorous cost-benefit analyses in projects that generate carbon benefits through forest conservation, regeneration, and agroforestry systems. Designed primarily for Inter-American Development Bank (IDB) stakeholders but applicable to similar institutions, it addresses a critical gap in the literature by offering the first comprehensive guidelines for determining the value of carbon benefits from forest-related development projects, in both ex-ante and ex-post analyses. The paper emphasizes the importance of establishing attributable project impacts through rigorous evaluation methods, selecting context-appropriate carbon content estimates, and incorporating sustainability assumptions into benefit calculations. It also includes references to key data sources that can be used as inputs in cost-benefit analyses and provides guidance on selecting appropriate carbon prices and discount rates.

JEL Codes: D61, Q54, Q57, O13

Keywords: Cost-benefit analysis, Forest conservation, Forest regeneration, Agroforestry, Carbon sequestration

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Acronyms

CO_2	Carbon dioxide
CH_4	Methane
GWP	Global warming potential
ha	Hectare
Mt C	Million tons of carbon
IDB	Inter-American Development Bank
IAMs	Integrated assessment models
MgC/ha/yr	Megagrams of carbon per hectare per year
Mha	Million hectares
SCC	Social cost of carbon
tC/ha	Tons of carbon per hectare
USD	United States dollar
MT	Metric ton

1 Introduction

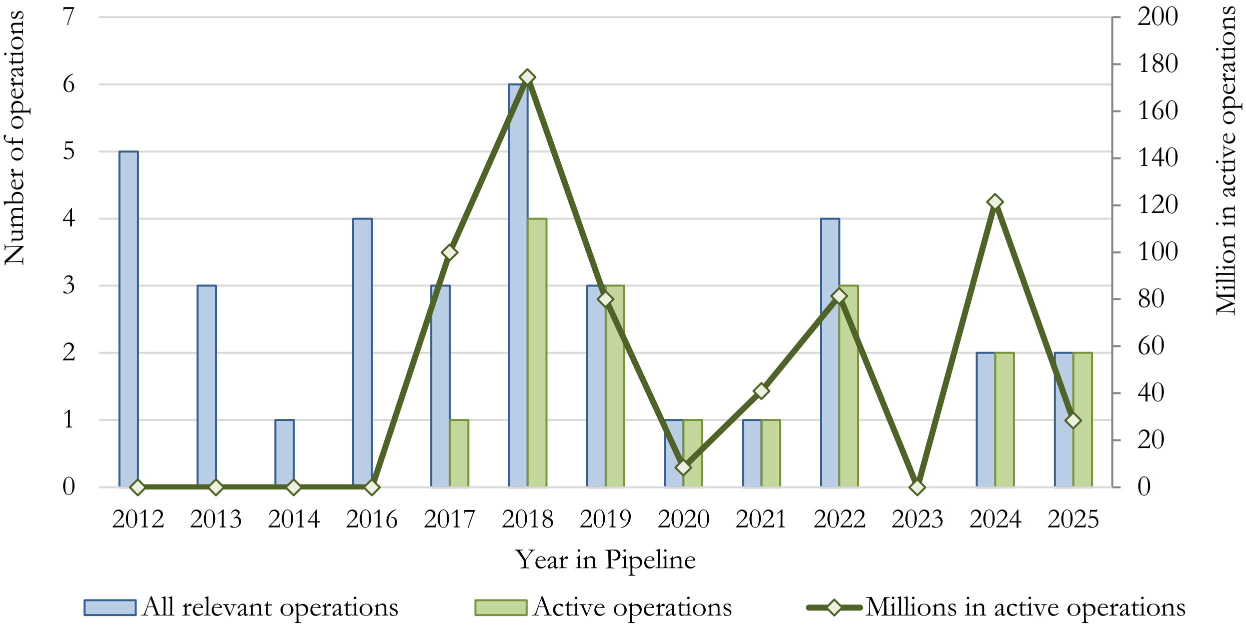
This technical note provides practical recommendations for conducting rigorous cost-benefit analyses of projects that generate carbon benefits by conserving and/or regenerating forest cover, or by integrating trees into croplands (agroforestry systems). These recommendations apply to both ex-ante and ex-post analyses, and they focus exclusively on determining the value of the environmental benefits associated with reduced carbon dioxide (CO_2) emissions, not on other benefits related to tree cover. There are two main reasons for this focus. The first is that carbon benefits usually exceed all the other benefits, such as sustainable harvests of timber and bushmeat, and the existence value of forests (Naidoo & Ricketts, 2006). The second is that the benefits from the avoided and sequestered CO_2 emissions are usually much easier to measure and assign a value to, thanks to publicly available datasets with country-specific information on the carbon content of forests and the carbon accumulation rates for new forest vegetation. However, when it is possible to quantify and monetize other benefits, they should also be included in the analysis.

To the best of our knowledge, this technical note is the first document to provide recommendations for assessing these types of projects. There is a body of literature focused on the aggregate carbon benefits from avoided deforestation and forest restoration (Busch et al., 2019; Busch & Engelmann, 2017), we could not find any practical recommendations on how to conduct cost-benefit analyses for projects that conserve or regenerate forests or integrate them into agricultural systems. This paper aims to fill that gap.

The technical note's intended audience is development practitioners, especially those working at the Inter-American Development Bank (IDB), given that these recommendations take into account current guidelines for evaluating IDB projects. However, these recommendations should also be useful to other practitioners from similar institutions. The historical and current volume of IDB operations expected to generate carbon benefits as a result of project activities highlights this paper's relevance. These recommendations would be relevant to 35 IDB operations in the pipeline since 2012 (totaling $1,305 million), of which 17 are still active (totaling $635 million, see Figure 1).

This paper is organized as follows: Section 2 explains the valuation of carbon benefits from avoided deforestation, while Section 3 focuses on benefits from forest regeneration. Section 4 addresses the benefits from agroforestry systems, and Section 5 discusses carbon prices and discount rates. Section 6 presents a brief discussion on the costs that should be included in the analysis, and Section 7 offers concluding observations.

Figure 1. Operations for which these guidelines are relevant



2 Determining the value of carbon benefits from avoided deforestation

Benefits associated with avoided deforestation come from avoiding CO_2 emissions that would result from releasing the below- and above-ground carbon contained in the forest vegetation. We need to define four parameters to estimate these.

First, we need to know how much forest area was protected by the project that otherwise would have been deforested (i.e., the extent of the avoided deforestation). This is the attributable avoided deforestation and is the most important parameter in the analysis. For an ex-ante analysis, this area should be estimated based on the size of the intervention area and the expected effect based on the existing evidence from similar interventions in similar contexts.

For an ex-post analysis, this would ideally come from an impact evaluation of the project that estimates the effect of the project's intervention on deforestation.[1] If such an estimate is not available, the project's impact on the preservation of forest areas should be estimated in a way similar to an ex-ante analysis, based on the project's vertical logic (including any results captured by indicators in the project's Results Matrix), and the existing evidence base. In this

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[1] According to the Project Completion Report guidelines: "If an impact evaluation is available, the Project Completion Report should include an assessment of the portion of changes in results that can be attributed to the project".

case, analysts should consider the external validity of the referenced studies and take their estimated effects from contexts that are as similar as possible to the project context. In the absence of evidence from similar contexts, another option is to use estimated values from existing meta-analyses of similar interventions, or in the absence of these, estimates from systematic literature reviews. Porter-Bolland et al. (2012) is a good example of a meta-analysis that estimates the average effect of protected areas. It is important to explain why the selected effects apply to the project being evaluated and provide evidence based on data from the project's area of intervention. Since the validity of the cost-benefit analysis hinges on the validity of the attributable effects, analysts should build a careful argument to support the attributable effects and include the main assumptions in this argument in a sensitivity analysis of the results.

For example, let's assume we are evaluating the benefits from a program that provided land titles to indigenous communities in Bolivia, for which no impact evaluation was done. We could use estimated effects from existing studies, such as Blackman et al., (2017), who find that a land titling program in Peru reduced deforestation by 71% per year, with the counterfactual deforestation rate at 0.37 percentage points. Before we use this estimated effect, we should evaluate whether the project's intervention is similar to the one in the study, whether the contexts are comparable (for example, baseline deforestation rates, land use patterns, and institutional contexts), and whether the magnitude of the estimated effect makes sense in the context of the project's intervention, ideally using data from the area of intervention that shows that an effect of this magnitude is indeed possible in this context. This last point is crucial. In this hypothetical case, if the observed reduction in deforestation following the project is 40% in the project's area of intervention, then to claim that the real effect is actually 71% based on the existing literature, we would need to build an evidenced-based argument to support that claim (for example, showing that deforestation in comparable areas was actually increasing in the same time period).

Additionally, it is important to define the future sustainability of the results, which requires making assumptions about deforestation trends in the project's area of intervention after the project ends. The best-case scenario is for a project's results to persist over time, in which case the avoided deforestation is permanent. The other end of the spectrum is a scenario where as soon as the project ends, deforestation increases to a point where all the avoided deforestation from the project is lost. Analysts should explicitly define the most likely scenario and provide a justification for it, since this determines the amount and timing of the avoided CO_2 emissions.

The second important parameter of the analysis, which also relates to the sustainability of the results, is the timeframe for calculating the net benefits, which should be explicitly stated and justified.

Third, we need to know the carbon content of the forest area(s) where the project prevented deforestation. The amount of carbon in the forest determines how much CO_2 is prevented from going from the ground into the atmosphere. Exact carbon content information is not always available at the subnational level, although some countries in Latin America have studies available (Table 1 presents a non-exhaustive list for Brazil, Colombia, and Mexico). When available, analysts should use region- or country-specific estimates.

When region-specific estimates are not available, the second-best option is to use other estimates from the literature. The best source of information on forests' carbon content by country comes from Saatchi et al., (2011), which estimates total carbon stocks (above and below ground) in tropical forests for 75 developing countries. The country-specific estimates are in three different tables in the "Supplementary Materials" section of the study.[2] Each table assumes a different tree cover threshold above which a plot of land can be considered forested and provides information on the total forest area, carbon biomass, and average carbon density in tons of carbon per hectare of forest. Table 2 reproduces part of Table S3c from Saatchi et al., but only shows information for countries in Latin America. This table gives the estimated carbon density for each country in Latin America, while islands in the Caribbean have all been grouped as "Caribbean*." For example, the mean carbon density for Argentina is 26 tons of carbon per hectare of forest, while for Ecuador it is 166.

Table 1. Example of studies with data on carbon content for forests at the subnational level

Study	Country	Region
Paiva et al. (2011)	Brazil	Federal District
Pereira et al. (2016)	Brazil	Ceará
Sanquetta et al. (2018)	Brazil	Brazil (whole country)
Tiepolo & Calmon, 2002	Brazil	Paraná
Ambientales et al. (2016)	Colombia	Guainía
Felipe et al. (2013)	Colombia	Vichada
Phillips et al. (2016)	Colombia	Colombia (whole country)
Sierra et al. (2007)	Colombia	Porce Region
Yepes-Quintero et al. (2011)	Colombia	Antioquia
Aguirre-Calderón & Jiménez-Pérez (2011)	Mexico	Nuevo Leon
de Jong et al. (2010)	Mexico	Mexico (whole country)
Mauricio Galeana-Pizaña et al. (2013)	Mexico	Magdalena River basin
Ordóñez et al. (2008)	Mexico	Michoacan
Pérez-Ramírez et al. (2013)	Mexico	Michoacan
Rodríguez-Laguna (2008)	Mexico	Tamaulipas
Vargas-Larreta et al. (2017)	Mexico	North-Western Mexico
Vizcaíno-Bravo et al. (2020)	Mexico	Veracruz

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[2] The Supplementary Material can be found here: https://www.pnas.org/doi/full/10.1073/pnas.1019576108#supplementary-materials

We can then convert the estimated carbon concentration to CO_2 and estimate the CO_2 emissions from the loss of a hectare of forest in any country. The difference in atomic mass between carbon and CO_2 determines the conversion factor. Carbon has an atomic mass of 12 and oxygen 16, so a CO_2 molecule has an atomic mass of 44. One ton of carbon is therefore equivalent to 3.67 tons of CO_2. Thus, losing a hectare of forest in Argentina would mean 26 tons of carbon in that forest would end up in the atmosphere, which is equivalent to 95.42 tons of CO_2 (26 tons C x 3.67 = 95.42 tons CO_2).

Table 2. Part of Table S3c from Saatchi et al. (2011)

		30%						
			Forest Carbon Stocks (Mt C)			Average Carbon Density (t C/ha)		
			Total					
Country	**Country Area (Mha)**	**Forest Area (Mha)**	**Low**	**Mean**	**High**	**Low**	**Mean**	**High**
Argentina	278	45	810	1,178	1,544	18	26	34
Belize	2	2	162	184	205	94	106	118
Bolivia	109	61	4,986	5,703	6,419	82	94	106
Brazil	853	442	48,429	54,374	60,305	110	123	136
Chile	76	21	955	1,115	1,274	46	54	62
Colombia	114	64	8,098	9,006	9,912	127	141	155
Costa Rica	5	3	268	300	333	96	108	119
Ecuador	26	13	1,802	1,981	2,159	138	152	166
El Salvador	2	1	28	34	39	42	51	60
French Guiana	3	2	357	386	418	148	160	174
Guatemala	11	6	470	537	603	83	95	107
Guyana	21	18	2,591	2,862	3,133	146	162	177
Honduras	11	6	441	506	571	70	80	90
Mexico	196	39	1,679	2,039	2,397	43	52	61
Nicaragua	13	5	507	566	625	106	119	131
Panama	8	3	357	396	434	105	116	128
Paraguay	40	21	407	582	756	19	27	35
Peru	130	73	10,624	11,694	12,762	145	160	174
Suriname	15	14	2,025	2,232	2,438	147	162	177
Uruguay	18	1	29	40	50	21	28	36
Venezuela	92	47	5,894	6,530	7,164	126	139	153
Caribbean*	23	7	301	353	406	40	47	54
Total Americas	**2,044**	**893**	**94,858**	**106,672**	**118,036**	**106**	**119**	**132**
Grand Total	**5,052**	**1,677**	**187,240**	**207,611**	**227,947**	**112**	**124**	**136**

The fourth parameter we have to define is the average lag between when the trees are cleared and when the carbon is emitted into the atmosphere. We estimate this lag time based on our knowledge of what will happen to the wood from the felled trees in the region of interest. The strongest assumption would be that the carbon is immediately released into the atmosphere, which is the case for forests cleared through fire. Most likely, the biomass from the felled trees will be used or disposed of in different ways, each with a different release time. We therefore have to assign a release time for each disposal method or use, and its share of the total biomass. For example, Jayachandran et al. (2017) assume an average lag from clearance to release of 10 years, which is consistent with "45% of the biomass being burned with immediate release, 45% decomposing with a mean survival of 15 years, and 10% being used as lumber, with the carbon stored for 30 years." The assumptions about this lag should be context-specific, since this contextual information will change both the share per use or disposal method and the decomposition rate.

In summary, the elements required for determining the value of the carbon benefits from avoided deforestation are:

1. The avoided deforestation attributable to projects, including the expected future deforestation after the project ends.
2. The timeframe for estimating the net benefits.
3. The carbon content of the forest in the area of intervention.
4. The assumed lag between deforestation and the release of carbon into the atmosphere.

Finally, the analysis should consider two additional elements: the monetary value of each ton of CO_2 and the discount rate used to convert future avoided emissions to their present value. Since these elements are common to the other analyses reviewed in these guidelines, we discuss them in Section 5.

3 Estimating the value of carbon benefits from forest regeneration

For projects focused on regenerating forest cover, either through tree planting or natural regeneration, the benefits of these new forest areas come from the carbon sequestered by the new trees. This analysis requires three main elements: the attributable net regeneration area, the carbon accumulation rate, and the length of the evaluation period.

The first element—the attributable regeneration area—is the area of regenerated forest that can be attributed to project activities. This element should ideally come from a rigorous impact evaluation that provides a causal estimate of the forest regeneration attributable to the project. The estimate is likely to be lower than the area reported from monitoring alone, since it will take into account that some regeneration would still have occurred in the counterfactual scenario with no project.

In the absence of an impact evaluation, the second-best option is to use the total estimated area regenerated by the project and then adjust this value to account for the expected natural regeneration that would still have happened without the project (the no-project counterfactual).

The strongest version of this approach would be in the same vein as a differences-in-difference estimation, which involves comparing the average regeneration rate prior to the start of the project to the one after the project (calculating the before and after difference) for both the project intervention area and a comparable area, and then calculating the difference in the differences between the project intervention area and the comparable area. For example, if the average yearly reforestation rate in the five years before the project was 1% and after the project was 1.5% in the project intervention area, and that of a comparable area was 1% before and 1.1% after, the difference between the before and after rates for the project area would be 0.5% and for the comparable area would be 0.1%. The difference between the differences would be 0.4%, which could be the effect attributable to the project, under the assumption that the comparable area is a valid comparator, where the reforestation rate of the project area would be expected to follow the same trend as the comparator area in the absence of the project (the parallel trends assumption). If there is no valid comparator, a weaker analysis could use the before and after differences for the project intervention area, with the underlying assumption that the pre-project trend serves as a reasonable no-project counterfactual scenario. This assumption is more credible when we can show that the pre-treatment values are fairly stable in the pre-treatment period.

The second element of the analysis is determining how much carbon is being sequestered by the newly regenerated area. As trees grow, they absorb carbon dioxide from the atmosphere and, through photosynthesis, transform it into glucose, which is then used to build their biomass (wood, branches, and roots).[3] How much carbon ultimately gets sequestered depends on multiple factors, such as tree species, soil characteristics, and local weather conditions like rainfall and temperature (Cook-Patton et al., 2020). Therefore, carbon accumulation rates vary by country and region.

We can use georeferenced data on forest growth and carbon accumulation rates to extrapolate site-specific carbon accumulation rates. Cook-Patton et al. (2020) have mapped out the carbon accumulation rates for the whole world and have calculated the averages by country. This appears to be the only existing dataset with a global scope. It covers 23 of the 26 IDB borrowing member countries (The Bahamas, Barbados, and Trinidad and Tobago are not included in the dataset). For each country, they estimate the yearly rate at which carbon accumulates per hectare of forest. These rates are the average annual carbon accumulation rates in a 30-year period (after 30 years, carbon accumulation slows). Table 3 shows the carbon accumulation rates from the “Supplementary Data” in Cook-Patton et al. (2020).[4]

We can use this information to calculate the amount of CO_2 captured through the recuperation of forest cover attributable to the project’s intervention. For example, a reforestation project responsible for the regrowth of 200 ha of forest in Bolivia could take credit for sequestering 566

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[3] A more instructional and detailed description can be found here: https://extension.psu.edu/how-forests-store-carbon (accessed Jan. 27, 2023), and here: https://www.creatingtomorrowsforests.co.uk/blog/technical-note-how-do-trees-store-carbon (accessed Jan. 27, 2023).

[4] These can be accessed from the published study’s website: https://www.nature.com/articles/s41586-020-2686-x#Sec15

tons of carbon (equivalent to 2,077.2 tons of CO_2) per year for the first 30 years following the initial reforestation.

Finally, we have to determine the length of the analysis period, which depends on two factors. The first is that the carbon accumulation rate decreases after 30 years (Cook-Patton et al., 2020), since biomass growth follows an S-curve that levels off approximately 30 years after planting. The second is the sustainability of the achieved results over the analysis timeframe, or the likelihood that the regenerated forest area will be preserved beyond a given year.

In summary, the required elements are:

1. The attributable area of forest regrowth, including an assumption about the sustainability of these areas.
2. The carbon accumulation rates in intervention areas.
3. The total time for which the benefits are evaluated.

Table 3. Carbon accumulation rates by country

Country	Mean aboveground rate (MgC/ha/yr)	Min. aboveground rate (MgC/ha/yr)	Max. aboveground rate (MgC/ha/yr)
Argentina	0.93	0.2	2.94
Belize	4.38	3.18	5.03
Bolivia	2.83	0.8	5.55
Brazil	3.95	1.33	5.84
Chile	1.73	0.68	2.81
Colombia	4.27	2.24	5.52
Costa Rica	3.51	2.05	4.37
Dominican Republic	3.2	1.83	4.11
Ecuador	3.53	2.15	4.87
El Salvador	2.66	2.19	3.19
Guatemala	3.58	2.03	5.05
Guyana	4.24	3.42	5.18
Haiti	3.34	1.93	4.37
Honduras	3.02	1.97	4.4
Jamaica	3.47	2.42	4.16
Mexico	2.69	0.28	5.23
Nicaragua	3.07	2.1	4.21
Panama	4.03	3.05	5
Paraguay	2.14	0.56	4
Peru	3.97	1.93	5.36
Suriname	4.22	3.64	4.91

Uruguay	1.55	0.82	2.42
Venezuela	3.6	1.63	5.14

4 Benefits from agroforestry systems

Projects promoting agroforestry systems are the third category addressed in this technical note. Agroforestry is “a diversified set of agricultural production systems that integrate trees in the agricultural landscape” (Zomer et al., 2016). In these projects, carbon is sequestered by integrating trees into croplands, which increases the amount of biomass (and carbon) per unit of land. The process of quantifying the additional carbon benefits from the agroforestry systems is similar to the other cases considered above:

1. First, we need to define what changes in areas with agroforestry systems can be attributed to the project. As with the two previous cases, this is the most important element of the analysis, since it is the starting point for quantifying the benefits attributable to the project. Ideally, we would use an impact evaluation to estimate the project’s effect on adopting these systems (accounting for what would have happened in a no-project scenario). However, if there is no impact evaluation, we must carefully select a value that reflects the expected effect, based on the best available evidence from similar interventions in similar contexts, supported by data from our area of interest. This will also allow us to construct a range of possible values that can then be used in a sensitivity analysis.
2. Second, we have to establish the counterfactual land use scenario so we can calculate the differential carbon benefits: the difference between the scenario with agroforestry (the project scenario) and the no-agroforestry scenario (no project). If the counterfactual scenario is agricultural land with no trees, 5 tons C/ha is the commonly used baseline value (Ruesch & Gibbs, 2008).
3. Third, we need to find an estimate of the carbon sequestration potential of agroforestry systems in the region where the project was executed. This data should ideally reflect the local context where these systems were implemented, but that level of regional disaggregation is rare, and so the second-best option is to use country averages available in the literature. Zomer et al. (2016) offer what appear to be the only estimates of the average carbon content for agroforestry systems by country. Table 4 reproduces part of Table S1 from the Supplementary Information section of that study.[5]
4. We can then calculate the total carbon benefits that can be attributed to the project as (1) x [(3) - (2)]. For example, a project in Honduras that led to the adoption of 60 ha of agroforestry systems on land that would have otherwise remained cropland could claim that it sequestered 60 x [55.4 – 5] = 3,024 tons of carbon (equivalent to 11,098 tons of CO_2).

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[5] This information can be accessed from the published study’s website: https://www.nature.com/articles/srep29987#MOESM11

5. Since these benefits will not materialize immediately, we must estimate the optimal temporal range, which depends on the specific characteristics of the agroforestry system (the arrangement and tree species used, as well as the local conditions, such as soil type and weather). This estimate requires an assumption about how long the landowners are expected to maintain their agroforestry systems, since at any point, they can choose to cut down the trees and not replant new ones. As with any other assumption, we need to explain why we chose a given time length and include evidence to support that choice.

Finally, it is also important to highlight evidence that agroforestry systems can increase agricultural productivity and incomes (Castle et al., 2021). Estimates of effects on income and/or consumption should also account for agricultural production for household self-consumption. These types of benefits should be included in project analyses if there is evidence that they exist.

Table 4. Average biomass carbon content for agroforestry systems, by country

	Average Biomass Carbon (t C/ha)	
Country	**2000**	**2010**
Argentina	17.8	14.2
Belize	74.1	74.0
Bolivia	40.1	41.9
Brazil	26.8	30.5
Chile	31.2	38.5
Colombia	52.7	52.4
Costa Rica	65.0	65.6
Dominican Republic	63.4	73.2
Ecuador	50.6	46.0
El Salvador	45.0	48.0
French Guiana	83.1	98.3
Guatemala	63.3	61.8
Guyana	50.1	50.7
Haiti	40.7	49.1
Honduras	50.5	55.4
Jamaica	86.8	89.3
Nicaragua	48.5	53.6
Panama	53.2	49.6
Paraguay	29.1	27.4
Peru	37.5	37.4
Puerto Rico	88.0	102.5
Suriname	62.5	64.0
Uruguay	19.8	20.4
Venezuela	44.0	46.0

5 Prices and discount rates

Two important variables for estimating the value of carbon benefits from a project are: (i) the price assigned to each ton of CO_2 (ii) and the discount rate used to convert the future stream of reduced emissions to present value. Neither has a defined set of best practices, so we aim to provide practitioners with the best set of options for analyzing them. We first discuss carbon prices and then discount rates.

5.1 Carbon prices

The monetary value assigned to a given amount of CO_2 released to the atmosphere is the cost associated with that negative externality. That value can be assigned in two different ways. The first is the most intuitive: we can estimate the damages produced by a given amount of CO_2 emissions, assign a monetary value to those damages, and then add them up to estimate the marginal damages associated with one additional unit of CO_2 being released into the atmosphere. This is the idea behind social cost of carbon (SCC) estimates. Based on this idea, there are two approaches for estimating these costs. The most common one uses the results of integrated assessment models (IAMs), which model the climate's response to changes in emissions. These climate estimates feed an economic damages function that estimates the damages from emissions. Given all the modelling choices, SCC estimates can vary greatly, although there has been a documented uptrend in published estimates (Rennert et al., 2022; Tol, 2023). Based on the same principle but a different approach, Pindyck (2019) uses survey responses with experts' opinions on the probabilities of extreme outcomes associated with climate change and the reductions in emissions needed to avert them. He then estimates the SCC as the ratio between these losses and the reduction in CO_2 emissions needed to avert them.

The second way to assign a monetary value to a given amount of CO_2 emissions is target-consistent pricing, where an implicit carbon price is estimated based on an emissions reduction target (such as the Paris Agreement target). The carbon price is set based on the estimated cost of reducing a given amount of CO_2 emissions, using aggregate marginal abatement cost curves (High-Level Commission on Carbon Prices, 2017; Stern et al., 2022).

From a public policy perspective, the second approach is the most relevant, since it is based on the targets set in the Paris Agreement, which has been ratified by 21 of the 26 IDB borrowing member countries. It also allows prices to change over time, reducing the need for ad hoc assumptions when projecting the future monetary value of CO_2. For reference, we present the estimated carbon prices per ton of CO_2 for each approach mentioned above (Table 5).

Table 5. Monetary values per metric ton of CO_2

Rennert et al. (2023) - 2% discount rate	$185	USD (2020)/MT CO2
Pindyck, 2019	$90	USD (2020)/MT CO2
High-Level Commission on Carbon Prices, 2017	$80	USD (2020)/MT CO2

5.2 Discount rates

Any economic analysis of a project's future costs and benefits requires discounting that future stream of net benefits to make them comparable over time. The rate used to discount future streams of net benefits significantly affects a project's economic evaluation, since it can drastically change its net present value (especially for projects with a longer time span). Higher discount rates favor projects with a more immediate stream of net benefits over projects whose net benefits come far in the future.

Since the projects we are concerned with here are likely to have net benefits in the future, the choice of discount rate is important, especially since the net benefits we focus on are associated with reducing emissions that drive climate change. The uncertainty regarding the possible damages from climate change (and hence regarding the benefits from reducing the emissions that cause it) make the choice of discount rate even more important when analyzing climate mitigation projects than it is for others.

There is currently no consensus on what discount rate should be used for climate change mitigation projects. However, the standard rate of 12% used in IDB economic analyses is excessively high and lacks theoretical support. This default practice punishes projects that by nature have potentially large but uncertain future payoffs. Thus, we recommend using a real discount rate of 2–4% per year.

This recommendation is based on two different approaches that yield a similar result. The first relies on expert opinions about choosing a discount rate. Given the ethical considerations attached to this choice, which are especially salient in relation to climate change, Nesje et al. (2023) surveyed philosophers and economists, asking them for their preferred real long-term social discount rate. They find significant agreement between the two groups of experts about what the social discount rate should be, with a mean preferred discount rate of 2.3% for both groups, and a range of 1 to 3% for economists (25th and 75th percentiles, respectively) and 1.3% to 2.8% for philosophers.

The second approach is based on the concept of global warming potential (GWP). GWP measures the amount of heat that one ton of a greenhouse gas traps in the atmosphere over a given period of time relative to one ton of CO_2, and it is used to convert different GHG emissions into CO_2eq units. The standard time horizon is 100 years for GWP calculations for GHG inventories under the Paris Agreement.[6] This time horizon implicitly signals that climate damages do extend far into the future, which is consistent with the atmospheric lifetime of CO_2 (200 to 2000 years [Archer et al., 2009]). A 12% discount rate would imply that damages are negligible beyond a couple of decades. Sarofim & Giordano (2018) show how a time horizon for calculating GWP could be translated into an implicit discount rate based on the damages generated by the temperature change associated with the emission of a given greenhouse gas (CH_4 in this case). Their results show that the commonly used 100-year time horizon translates to an implicit discount rate of approximately 3.3% (with an interquartile range of 2.7% to 4.1%). By comparison, applying the conventional 12% discount rate used for development projects would mean treating climate impacts beyond roughly 22 years as economically negligible, which is fundamentally inconsistent with the atmospheric lifetime and the long-term nature of climate change.

6 Quantifying the costs

The process of quantifying costs must include all costs that made attaining the project's results possible. We separate these costs into different categories:

1. First, all project costs associated with the activities that directly contributed to bringing about the carbon benefits should be included as part of the analysis. For example, in a reforestation project, these would include all costs of planting materials (tools, grafted trees, seeds, fertilizer, etc.), as well as the administrative costs required to successfully organize the activities, including monitoring and evaluation costs. Given that most IDB projects include several activities that may not be directly associated with those that brought about the carbon benefits, administrative costs, if shared with other activities, should be allocated in proportion to the weight in the overall project budget of the activities generating carbon benefits. These assumptions should also be explicitly stated in the analysis, and the analyst should consider including this parameter in the sensitivity analysis.
2. Second, the analysis should also include all maintenance costs required for the sustainability of the achieved results. These could be the costs of maintaining physical infrastructure and/or the operating costs of any governance institutions that may be needed to protect any natural resource. These costs should be analyzed using the same timeframe as the one used for evaluating the stream of future carbon benefits.
3. Finally, in some cases, the analysis should include the opportunity costs associated with other land uses. Given that the objective is to compare the net benefits of the situation with the project to a counterfactual situation of no project, under some no-project counterfactual scenarios, the land is used for other economic activities. These uses may have negative externalities, which are considered benefits associated with the program (when they are

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[6] Paris Rulebook [Decision 18/CMA.1, annex, paragraph 37] (https://unfccc.int/resource/tet/0/00mpg.pdf)

avoided), but they may also generate economic benefits for some people that will no longer be available if the land is forested. In these cases, these other economic benefits represent an opportunity cost of implementing the project's activities, and as such should be included in the analysis.

7 Conclusion

This technical note aims to equip IDB teams with practical recommendations for conducting thorough cost-benefit analyses of initiatives that generate carbon benefits by conserving or regenerating forest cover and by integrating trees into croplands through agroforestry systems. We have primarily focused on the data required for analyzing the economic performance of these types of projects, providing the best available data sources and explaining how they can be interpreted and used to assign a value to CO_2 benefits. We also discuss other elements required for a cost-benefit analysis: the monetary value per ton of CO_2, the discount rate, and the costs associated with bringing about the results.

Although these recommendations target IDB teams, we believe they will also be relevant for other development practitioners at similar institutions. By following these recommendations, practitioners can conduct more reliable and comparable cost-benefit analyses to make informed decisions on implementing and funding forest cover-related projects and to properly evaluate and learn from previous experiences.

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